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PATENT

**SYSTEM AND METHOD FOR OPTICAL PORT INSPECTION FOR
TELECOMMUNICATION SYSTEMS AND DEVICES**

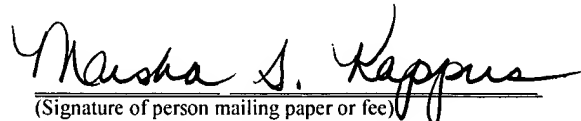
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SYSTEM AND METHOD FOR OPTICAL PORT INSPECTION FOR TELECOMMUNICATION SYSTEMS AND DEVICES

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to optical ports and optical connection components used therein for optically coupling fibers such that an optical signal traverses the connection between the fibers. More particularly, the present invention relates to a system and method for inspecting optical ports for occlusions that might impede the optical signal.

2. Description of Related Art

As is known in the art, optical signals can be transmitted over optical fibers from location to location. Each optical fiber is optically connected or coupled to other fibers and/or optic processing equipment using optical components such as connector, adapters, optical ports and the like. At an optical connection, a pair of optical fibers transmits and receives optical signals across coupling surfaces formed at the termination end of the respective fibers. Optical connections have long been known as a primary source of signal degradation due to poor coupling characteristics such as misalignment of the optical axes, excessive spacing between coupling surfaces and contaminants which occlude or partially occlude the optical signal.

Normally, an optical connection takes the form of an adapter that engages a pair of optical connectors. The adapter, usually having a female-to-female connection, mates with the optical connectors, usually being a male connection. Each male optical connector secures the coupling surface of the fiber in a predetermined position and the

adapter engages the optical connectors at a predetermined position such that the fibers are optically coupled to each other. Dust, dirt, pollen and other airborne contaminants often present a problem for transmitting optic signals because they are often introduced at the optical connections. In addition to the contaminants mentioned above, streaks from alcohol, acetone, oil stains and residual films can present a problem for optical transmissions. Once present, these contaminants degrade the optical signal, sometimes to a point where the transmission is completely obstructed. Inspecting optical fiber connections has been a continual problem in the telecommunications industry due to the minute cross-sectional size of the coupling surface to be inspected and the additional difficulty in accessing the recessed coupling surfaces. Rarely can contaminants be detected using the naked eye, therefore fiber microscopes have become popular for inspecting optical fiber connections.

Hand-held fiber microscopes presently known in the art are used for such inspections. These fiber microscopes allow an operator to peer into an eyepiece and directly view a coupling surface. Fiber microscopes include magnification and focusing optics for magnifying the coupling surface of a fiber while disposed on an optical fiber connector. In use, an operator normally positions the fiber coupling end of a fiber in the optical path of the uptake optics of the microscope and then peers into an eyepiece to examine the fiber coupling surface. Steadying the fiber microscope for accurately visualizing the fiber coupling surface is often difficult due to the high degrees of magnification necessary to examine the coupling surface in detail. Therefore, many fiber microscope models also come equipped with special adapter caps that easily attach to the uptake optics of the fiber microscope and which engage a particular type of male optical connector.

While this system works well for male optical connectors, problems occur when a male connector is engaged in an adapter and cannot be disengaged for inspection. This is the case with optical ports, especially bulkhead ports where a patch fiber is connected to

an inaccessible side of a bulkhead adapter. Currently, *in situ* inspections are impossible because fiber microscopes cannot resolve an optical coupling surface mated to an adapter. The normal method for inspecting a coupling surface using a fiber microscope is to disengage the optical connector from the adapter and then inspect the optical connector separately. Current fiber microscope models are simply too big to be inserted into most adapters. Presently available optical fiber microscopes cannot be used to inspect crucial portions of any female fiber component, such as optic ports or miniature optical sleeves.

Furthermore, the area of the aperture opening of many adapters has been reduced. This is especially true for high density matrix port and block optical port styles where the entry area is condensed to make space for more optical connection in an equivalent area, thereby making inspection by current techniques even more difficult. Presently, several fiber scopes are available, however, the inspection head (encasing the lens and light shaft) and borescope insertion are large (more than 1/4 inch in diameter) such that it is impossible to access high density port such as MU, MT, LC and LX component types on optical cross connect, optical ultrabroadband DACS unless neighbor fiber connectors are removed.

Another problem facing the telecommunications industry is the current trend of component manufacturers equipping optical components with shutters. Both connector and adapters are currently equipped with shutters. Optical ports with shutters, such as E2000 (available from and trademarked by Diamond S.A.), LX.5 (available from and trademarked ADC Telecommunications, Inc., Minneapolis, MN) make visual inspection even more problematic because the coupling surface is protected by a shutter. Shutters can be affixed to a component externally, or in the case of some types of adapters, internally and recessed from the threshold of the adapter. In more advanced optical components, these shutters are part of a shutter system which cannot be actuated manually without great difficulty for the operator. With respect to these components, even if the fiber microscope's size did allow for entry into the adapter, the target surface would remain hidden from view by the shutter.

A final problem associated with visually inspecting optical components is that moderate power lasers are used to drive the optical signal. Whenever an operator peers into an optical port, care should be taken to avoid the laser beam etching the operator's retina. Laser sources have auto shut-off options; however, intermediate passive and active components, such as patch panels and optical cross-connect ports, do not have such options. There presently exists a great danger to the vision of inspection personnel while the laser source is on.

Currently, there is no solution for the problems described above. If db losses are higher than expected for an optical port, the usual procedure is to pump dry air onto the optical port hoping to free foreign particles from the coupling surface. However, this assumes that contaminants are actually present. Since visually inspecting the optical port is impossible, foreign particles may or may not be present. Once the coupled surface has been sufficiently flooded with dry air, the circuit db losses are compared to the previous results. If db losses are reduced, then the process was a success and is repeated until no further db gain can be achieved. Otherwise, the complete board is replaced. Once removed and sent for maintenance, savvy technicians typically open the module case to access the internal optical patch fibers, disengage the optical connectors and inspect the connectors using a fiber microscope as described above. Because optical card failure is so often rooted with the optical connection to the card, it behooves technicians to inspect the optical ports prior to performing any more complex diagnostics on the card.

SUMMARY OF THE INVENTION

5 The present invention relates to a system and method for *in situ* inspection of optical ports for occlusions that might impede an optical signal. The present invention utilizes a mini-borescope of the type having a borescope insertion tube of less than two millimeters in diameter. The mini-borescope may utilize a video camera for capturing images of the target and adjustably magnifying the target image for display. In addition, one of a plurality of component type optical adapters is coupled to the mini-borescope insertion tube. Each particular type optical adapter allows the insertion tube to be inserted and aligned to a corresponding type of optical component, for instance, if the optical adapter is an SC-type male connector, then the insertion tube will be readily accepted by an SC-type female adapter. Also included in the optical adapter is a protective sleeve which surrounds a portion of the mini-borescope insertion tube. The protective sleeve provides the insertion tube with added rigidity, thereby lessening the likelihood of accidentally bending the tube during insertion. Optical adapters may also cooperate with component shutter systems for actuating protective shutters during engagement of the optical adapter, thereby exposing the coupling surface without manual intervention.

BRIEF DESCRIPTION OF THE DRAWINGS

The novel features believed characteristic of the present invention are set forth in the appended claims. The invention itself, however, as well as a preferred mode of use, further objectives and advantages thereof, will be best understood by reference to the following detailed description of an illustrative embodiment when read in conjunction with the accompanying drawings wherein:

FIG. 1 is a cross-sectional view depicting a prior art fiber optic connector and connector adapter as is commonly used in the telecommunications industry for optically connecting fiber optic lines;

FIG. 2 is a cross-sectional view representing a optical fiber connector being inspected *in situ* in an optical port configured from an optical adapter being attached to the bulkhead of an optical module;

FIG. 3 is a view of a system for optical port inspections for optical devices in accordance with an exemplary embodiment of the present invention;

FIGs. 4A and 4B are cross-sectional views of an optical adapter of the present invention and a typical optical connector in side-by-side depictions;

FIG. 5 is a cross-sectional view depicting a typical optical port inspection as illustrated with respect to an SC-type environment in accordance with an exemplary embodiment of the present invention;

FIGs. 6A through 6E are cross-sectional diagrams depicting the stages of insertion of an *LX.5* connector into an *LX.5* adapter in accordance with the prior art;

FIGs. 7A and 7B are cross-sectional diagrams of an optical adapter in accordance with an exemplary embodiment of the present invention and of a typical *LX.5* connector; and

FIGs. 8A through 8E are cross-sectional diagrams depicting an *LX.5*-type mini-borescope optical adapter engaging an *LX.5*-type adapter for inspecting a coupling

surface of the optical fiber therein in accordance with an exemplary embodiment of the present invention.

Other features of the present invention will be apparent from the accompanying drawings and from the following detailed description.

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DETAILED DESCRIPTION OF THE INVENTION

FIG. 1 is a cross-sectional view depicting a prior art fiber optic connector and connector adapter as is commonly used in the telecommunications industry for optically connecting fiber optic lines. The specific connector and adapter type being illustrated in **FIG. 1** is that of SC-type connector/adapter component, *i.e.* SC connector **112** and SC adapter **102**. However, an artisan having ordinary skill in the art will readily realize that the use of an SC type components is merely exemplary and that any type of connector component might be substituted for the SC type components without departing from the original scope and intent of the present invention described herein. Other exemplary component types currently used in the optical communications arts are SC, ST, FC, E2000, LC, LX, MU, MT components types. A complete understanding of the functionality of a particular type of coupling component for that matter, any type of optical coupler is not necessary for understanding and practicing the present invention. Therefore, the components depicted in **FIG. 1** will be only briefly described touching on only the elements that are necessary for gaining a better understanding of the present invention. The SC-type components were selected for discussion because the aforementioned type of component is representative of a broad class of components that do not contain internally positioned shutter mechanisms.

Depicted in **FIG. 1** is SC connector **112** and SC adapter **102**. SC connector **112** is first shown disengaged and apart from SC adapter **102** and then represented engaged within the body of SC adapter **102**. Engagement is possible only when oppositely sexed, but matching component types are brought together and mated. Generally connectors are male and adapters are female. Observe that SC adapter **112** rigidly disposes fiber core (or simply fiber) **118** at a predetermined position and orientation within SC adapter **102** with respect SC adapter body **114**. As fiber **118** is extremely flexible and prone to breakage and end damage, fiber **118** is further constrained in ferrule **116** which, in turn, is mounted

within the interior of body **114**. Body **114** holds ferrule **116** in a fixed orientation and position such that coupling surface **119** of fiber **118** is optimized to receive and/or transmit optical signals to another fiber.

Turning to SC adapter **102**, optical sleeve or ferrule tube **106** aligns fiber **118** by
5 guiding ferrule **116** along its interior wall upon the insertion of SC connector within SC adapter **102**. Clearly, the inner diameter of ferrule tube **106** is slightly greater than the outer diameter (d_f) of ferrule **116**. Ferrule tube **106** is rigidly positioned within the interior of adapter body **104**. The interior surfaces of body **104** cooperates with the exterior surfaces of body **114** such that fiber **118** is rigidly held in a predetermined
10 position with respect SC body **114**. Ferrule tube **106** provides a guide means for the insertion of ferrule **116** whenever an SC adapter is engaged within adapter **102** which aligns coupling surface **119** of fiber **118** for optical coupling with another fiber inserted within ferrule **106** from the opposite direction. Notice that the particular adapter configuration depicted in the Figure is an SC-to-SC adapter meaning that the adapter is
15 configured to receive an SC connector at either end. This, of course, is merely exemplary as many adapters are configured for accepting a different type connector at either end while aligning the fibers from each for optical coupling. For instance, a typical optical adapter may be configured to adapt a first optical connector type to a second optical connector type (*e.g.*, FC to SC or ST to SC or some other combination of
20 connector types). With respect to the descriptions below, an optical port may be considered as being synonymous with an adapter, wherein the adapter is affixed to the surface of a device, such as an optical module. These optical ports are often referred to as bulkhead adapters because they physically traverse a bulkhead of an enclosed unit and provide ingress and egress means for signals to the interior of the device.

25 With respect to the depicted example, SC adapter **102** has at its furthest exterior extent optional external shutter **108**. Dirt, dust, pollen and other particulate matter are of particular concern with respect to optical connections because even a

particulate of minute dimensions may impede the flow of the optical signal. Thus, in the case of adapter **102**, when the optical port is not in use, shutter **108** is manually closed, or in most cases, is automatically closed when an SC connector is not present, thus protecting fiber **118** from becoming contaminated with airborne particles. External shutter **108** provides still another valuable function in that many times fiber **118** may emit an active laser signal even though adapter **102** is not in use. In those cases, the card or module on which SC adapter **102** is attached will emit a laser beam which may be harmful to the retina of persons happening to gaze at the adapter.

Observe that SC adapter **102** is connected to bulkhead **120** through an adapter orifice in bulkhead **120** and secured in position by means of a pair of flexible members **109**. Thus, as shown in the present Figure, SC adapter **102** may be mounted on the front or rear bulkheads of any card or module used for the transmission or processing of optical carrier signals, but normally, SC adapter **102** is mounted on the inner wall of bulkhead **120** thereby creating an exposed optical port on the outer wall of bulkhead **120**.

As mentioned above, dirt, dust, pollen and other particulate matter may become lodged on the coupling surface of fiber **119** which reduces optical transmission performance. In addition, coupling surface **119** of fiber **118** is also prone to scratching from improper handling and/or contact with another fiber during coupling which further impedes the flow of the optical signal from one fiber coupling surface to another. Thus, prior coupling a pair of optical connectors (*i.e.*, an optical connector to an adapter), it is a good practice to visually check the optical connections for any foreign matter that may occlude the coupling surfaces and impede the flow of the optical signal. Similarly, whenever an optical card or module exhibits a higher than normal error rate or fails outright, checking the optical connections for foreign occluding matter as a precursor to troubleshooting the internal electronics may save valuable time and expense.

However, visually inspecting the coupling surface with the naked eye is virtually impossible due to the extremely minute diameter, d_i , of the cross section of coupling

surface **119** on fiber **118**. Coupling surface **119** is magnified in order to visualize any substance that may interfere with the transmission to or from the respective fiber coupling surfaces. Normally, a hand-held fiber microscope such as those available from Noyes Fiber Systems in Belmont, NH or Westover Scientific in Woodinville, WA are used for such inspections. Typically, these fiber microscopes include magnification and focusing optics for magnifying the coupling surface of a fiber while disposed on an optical fiber connector. Magnification ranges are available on various fiber microscopes from between 200X to 600X for imaging the coupling end of a fiber. In use, an operator normally positions the fiber coupling end of a fiber in the optical path of the uptake optics of the microscope and then peers into an eyepiece to examine the fiber coupling surface. As can be imagined, steadying the fiber microscope for accurately visualizing the fiber coupling surface is often difficult due to the high degrees of magnification necessary to examine the surface. Therefore, many fiber microscopes models also come equipped with special adapter caps which easily attach to the uptake optics of the fiber microscope which engage a particular type of optical connector such as an SC, ST or FC connector. Once a connector is connected into the adapter cap of the fiber microscope, the fiber coupling surface is automatically aligned with an optimal viewing orientation for visualizing the fiber coupling surface and, as such, is easily examined for occlusions by an operator.

While this system works well for male optical connectors, problems occur when a connector is to be examined *in situ*, that is, in place while engaged in an adapter, for instance, when an optical connector is engaged in a female adapter that is configured on a bulkhead of an optical module or processing card.

FIG. 2 is a cross-sectional view representing an optical fiber connector being inspected *in situ* in an optical port configured from an optical adapter being attached to the bulkhead of an optical module. Notice that **FIG. 2** depicts an identical SC adapter/connector combination **200** as shown above with respect to **FIG. 1** which, as

alluded to above, is only one possible optical coupling configuration that might be present for examination. With respect to the Figure, fiber microscope **250** has been positioned along an optical axis that would allow the best vantage point for viewing the coupling surface **219** of fiber **218**. Notice that d_l , that is the diameter of the optical uptake portion of fiber microscope **250**, is extremely large with comparison to the diameter d_f of ferrule **216** or ferrule tube **206** and also that diameter $d_l \gg d_f$ such that neither lens **252** nor ferrule **254** can be received within the opticalport. Thus, as is plain to see, fiber microscope **250** cannot be inserted within the hosing **204**, much less within the inner extent of ferrule tube **206** on SC adapter **202**. Therefore, an operator is left with the alternative of positioning fiber microscope **250** at the outer extent of adapter **202** and peering through that opening in an effort to visualize coupling surface **219** of fiber **218**. In such a situation, the operator is rarely ever able to visualize an image of anything other than the first few millimeters of the interior of adapter **202** due to the optical focal distance of fiber microscope **250**. It is impossible, given the prior art technology, to focus on coupling surface **219** of fiber **200** when that surface is recessed within ferrule tube **206** of the outboard side of adapter **202**. If the adapter is positioned such that SC connector **212** can be disengaged from adapter **202**, then the operator can visually inspect coupling surface **219** of fiber **218** using fiber microscope **250**. If, however, as is often the case, the coupling end of fiber **212** is completely enclosed within the module housing, then fiber coupling surface **219** cannot be inspected for occlusions or scratches without physically removing the module from the system, disassembling the module, removing the fiber patch cord, including uncoupling SC connector **212**, and then visually inspecting the card with fiber microscope **250** as discussed above. This shortcoming in the prior art has led to most operators implementing a procedure of first attempting to clean the coupling end of fiber **212**, re-testing the card, and then upon an unsuccessful test, removing the card for further evaluation. The cleaning process has currently evolved to the point where most operators merely open the shutter (if the adapter is configured

thusly), blow a puff of air within the extent of the adapter hoping to clear away any debris from the optical coupling surface, and then re-test the card.

A second, and sometimes more serious problem with this procedure, is the fact that many times fiber **218** will be live, carrying an optical signal, emitting a laser beam from the coupling end. Thus, when the user peers into adapter **202** with fiber microscope **250**, even though the user cannot properly focus on coupling surface **219** of fiber **218**, the full force of the laser beam may be received within lens **252** and directed straight to the operator's retina which can lead to serious retinal damage to the operator. What is needed is a safe and effective means for examining the coupling surfaces of optical fibers within a plurality of different adapter types while the adapter functions an optical port on an optical module, whereby the inspection is accomplished *in situ*, while the module remains in place and, if possible, in use.

FIG. 3 is a cross-sectional view of a system for optical port inspections of optical devices in accordance with an exemplary embodiment of the present invention. The present invention is composed of two primary components, the first being an industrial mini-borescope of the type conventionally used in the visual inspection arts, and the second being a replaceable optical port adapter for configuring the borescope for inspecting a variety of different types of optical connector adapters. With respect to **FIG. 3**, mini-borescope **300** consists of mini-borescope insertion tube **304**, handle **302**, and eyepiece **308**. With respect to some borescope models, handle **302** and mini-borescope insertion tube **304** are more properly referred to as a videoscope, as handle **302** contains a built-in video camera for transmitting a video signal to monitor **306**. Often eyepiece **308** is replaced with monitor **306** which is mounted on handle **302** for displaying the target image. Operationally connected to mini-borescope **300**, power supply and control device **310** supplies power to the electronics in mini-borescope **300** and includes a xenon light source with the corresponding light intensity adjustment controls. Optionally, power supply and control device **310** might also contain image enhancement processing

capability for augmenting images received from mini-borescope **300**, along with the software necessary for invoking the image enhancement algorithms. Power supply and control device **310** may also be fitted with monitor **306** for displaying the target image.

It should be understood that the descriptions of mini-borescope **300** and power supply and control device **310** are merely exemplary and the specific configuration of the mini-borescope in no way affects the performance or use of the present invention, with the exception of that described below. One feature that distinguishes mini-borescope **300** from conventional borescope devices is the diameter of mini-borescope insertion tube **304**. Typically, borescope insertion tubes have a diameter of 5-16 millimeters, of which the most popular is the eight millimeter diameter borescope insertion tube. With respect to the present invention, an exemplary mini-borescope is one in which the diameter of the mini-borescope insertion tube **304** is approximately equal to or slightly less than a typical fiber optic ferrule disposed within a conventional optical connector. Typically, the diameter of a fiber optic ferrule is approximately 1.2 millimeters in diameter.

Connected to the lens end of mini-borescope insertion tube **304** is mini-borescope-to-optical port adapter (BOPA) **360**. The body of BOPA **360** is similar in construction to the type of connector that is compatible with the optical port to be inspected. Therefore, the borescope-to-optical port adapter is also compatible with the optical port to be inspected. Thus, BOPA **360** engages a like-type optical port of the opposite sex in much the same manner as optical connector engaging a like-type adapter. It follows then that BOPA **360** cannot be a single component type because it should be compatible with a variety of different optical port types. Mini-borescope insertion tube **304** is be reconfigured with a matching type of BOPA **360** for the type of adapter in the optical port to be inspected. Therefore, a variety of different type BOPAs that are compatible with optical ports to be inspected should be available.

Subsequent to BOPA **360** engaging an optical port, the coupling surface of an optical fiber is oriented on the optical axis of the borescope's lens and within its proper

depth field of view. An image of the coupling surface of the fiber can then be captured by mini-borescope **300**, thereby allowing the operator to safely examine the coupling surface for occlusions or scratches that might impede an optical signal.

Optical port contamination and/or optical coupling surface defects can reduce overall system gain by several db thus severely affecting the Bit Error Rate (BER). In accordance with an exemplary embodiment of the present innovation, inspecting an optical port using like-type BOPA **360** and mini-borescope **300** reduces the cleaning process time normally involved with examining an optical port of an optical occlusion, *i.e.* repeatedly blowing air into the port and then measuring the change in power.

Occlusions and scratches on an optical fiber's coupling surface are easily recognized from a magnified image of the coupling surface, thereby positively identifying a source of trouble, or eliminating a possible trouble spot, before condemning an optical module or board. By accurately diagnosing the source power loss as port contamination and/or optical coupling surface defects, unnecessary board replacement can be avoided and, in many cases, the defective optical port can be cleaned while remaining in place. Even in cases where the board is removed for maintenance, the optical port is eliminated as a potential trouble spot, that is, of course, unless the operator is unable to refurbish the coupling surface in the field, and even then turn-around time for card maintenance is greatly reduced because one source of the power loss has been identified prior to the card being removed for service. Clearly, the present invention provides a mechanism for identifying problems with optical ports *in situ* and most problems can be resolved in the field with little effort by the operator. Moreover, the application of the present invention is not limited to operational equipment. Instead, utilization of the present invention on optical test equipment can lead to a reduction in errors from optical testing instrument due to contamination, surface defect or poor optical transmission, just as may be realized from operational equipment. Finally, because mini-borescope **300** uses a mini-video camera for transmitting a video signal to monitor **306**, eyepiece **308** is eliminated and

therefore the incidences of retina damage due to power laser source is greatly reduced, as is a corresponding reduction in liability.

5 The operation of mini-borescope **300** is extremely basic, not much more complicated than engaging an optical connector into the port to be inspected. To inspect an optical port, the operator first selects the appropriate size borescope insertion tube. Tube diameters vary from approximately 1.2 millimeters to 1.7 millimeters, and even smaller depending on the particular manufacturer's model design. The mini-borescope is then turned on (recall that the borescope is actually a videoscope that captures images of a target using a mini-video camera). The operator equips the mini-borescope insertion tube **304** with a borescope-to-optical port adapter that matches the type of optical port to be examined and locks the optical adapter onto mini-borescope insertion tube **304**. BOPA **360** is then inserted directly into an optical port which is similar to inserting an optical connector into the port. Images of the coupling surfaces are then captured and displayed for the operator on monitor **306**. Often the monitor is a lightweight LCD panel that can be physically joined to handle **302** for convenience. Because the images are projected on monitor **306**, the condition of an optical port can be positively determined even when the power laser source is active without the possibility of retina damage from laser light. Prior art borescopes frequently employ a laser filter to protect the operator's retina from damage, but the chance still exists of light leaking past a filter. Finally, the operator can make appropriate adjustment to focus and lighting for best images, while BOPA **360** can be manipulated forward and back or from side to side to examine all aspects of the optical port, including the coupling surface of optical fibers, optical sleeves, and even the connectors, or adapters, themselves.

25 In accordance with exemplary embodiments of the present invention, optical ports can be visually inspected and accurate results can be obtained as to the condition of the optical ports (versus guessing). By using the present invention, troubleshooting time can be reduced. In addition, because operators are not subjected to a directed view of the

target surface, laser damage to the retina is impossible. Moreover, exemplary embodiments of the present invention can be configured for virtually any optical port that currently mate to an optical connector, including ports with deeply recessed coupling surfaces, high density matrix blocks, shuttered ports, internal or external, and the myriad
5 connection components that were heretofore not inspected at any stage (*i.e.*, ferrule tubes, etc.) Current production mini-borescope models exist that can adapt to any type of fiber connectors with ferrule a diameter of 1.2 millimeters; however, smaller diameters are possible and will be available in future production models. Because the mini-borescope insertion tube engages a borescope-to-optical port adapter using BOPA 360, neither the
10 borescope microlens or the fiber cores are subject to accidental scratches or damage. BOPA 360 maintains a predetermined interval between the borescope microlens and the coupling surface of the fiber that cannot be adjusted by the operator.

The borescope-to-optical port adapter protects the borescope barrel from bending, thus breaking its internal lens. It also acts as an adapter to optical fiber connectors to
15 keep the borescope lens and optical ports from scratching. Still further, with regard to other embodiments, the borescope-to-optical port adapter maintains proper depth field of view and facilitates insertion into optical ports or bulkheads with shutters (*LX0.5*, *E2000*, etc.). In accordance with an exemplary embodiments of the present invention, borescope-to-optical port adapters can be used to convert a mini-borescope to inspect
20 laser transmitter and receiver ports, optical amplifiers, high-density (high port counts) optical switches, and optical cross connectors. With regard to other embodiments, the borescope-to-optical port adapter can be used to convert an mini-borescope to inspect optical testing instruments such as O/E (optical-to-electrical) and E/O converters, power meters, Optical Time Domain Reflectometers (OTDR), laser modulators, Dense
25 Wavelength Division Multiplexing (DWDM) system test sources, Polarization Mode Dispersion (PMD) and Polarization systems, non-contact interferometers (such as ZX-1 micro available and trademarked by Digital Optical Research Company, Phoenix, AZ).

Finally, with regard to still other exemplary embodiments, the borescope-to-optical port adapter can be used to convert a mini-borescope to inspect an optical fiber scope, optical sleeves, optical patch panel connectors, optical fiber connectors, fiber optic bulkheads, bulkhead adapters, fiber optic stripping tools (such as Micro-Strip), Radio Frequency Synchronous Add/Drop Multiplexers (RF SMA) ports.

FIGs. 4A and 4B are cross-sectional views of a borescope-to-optical port adapter of the present invention and a typical optical connector in side-by-side depictions, respectively. Again in this illustration, a SC-type connector is used for the comparison. Turning to **FIG. 4A**, an enlarged cut-a-way view of a mini-borescope rod is shown in conjunction with the BOPA of the present invention. Mini-borescope insertion tubes are comprised of two basic elements: the light element and the viewing element. Optical rod **466** traverses the length of mini-borescope insertion **404** tube from the handle to lens **467** and is typically surrounded by light shaft **464**. Light shaft **464** conveys from a light source and emits light beams from end **475** for illuminating a target. Light rod **464** may be a single optical rod for transmitting light, but often light rod **464** is configured from a plurality of smaller individual optical fibers which are bundled around optical rod **466** and optically connected to a light source via a coupling flange. In any case, both light rod **464** and optical rod **466** are securely held within mini-borescope insertion tube **404**. On most standard borescope models, the insertion tube is rigid and strong enough to provide adequate protection for both the optical rod and the light fibers against accident breakage from cantilever tensions applied across the insertion tube. However, such is not usually the case with respect to mini-borescopes. Mini-borescope insertion tube **404** stemming from a mini-borescope is much less rigid than that of its conventional counterpart, and optical rod **466** can often be damaged if insertion tube **404** is bent. Therefore, in accordance with another exemplary embodiment of the present invention, protective sleeve **462** surrounds insertion tube **404** and provide additional resistance to accidental bending. The additional rigidity provided by protective sleeve **462** allows

BOPA 460 to be mated with a variety of types of optical port, even those requiring BOPA 460 to be forcibly engaged to the optical port.

It is expected that protective sleeve 462 locks or snaps to the exterior of insertion tube 404 via locking means 468 at a predetermined location and that optical adapter body 414 is permanently fastened to protective sleeve 462. Recall that the components cannot properly mate unless the components are of a like type and opposite sex. Therefore, in that case, a particular BOPA 460 is selected based on the type of optical adapter body matching the optical port to be inspected. Once chosen, the entire protective sleeve/optical adapter body combination (462/414) is locked into place on insertion tube 404. However, in accordance with another exemplary embodiment, optical adapter body 414 may be removed and replaced from protective sleeve 462. In this case, protective sleeve 462 may remain attached to insertion tube 404 while a matching type of optical adapter body 414 is selected for an optical port to be inspected, and that optical adapter body is then locked onto protective sleeve 462 (lock not shown).

As in the illustrations described above, BOPA 460 depicted in the present Figure is that of an ST-type optical adapter designed for mating with a corresponding ST-type adapter. Still again, the ST-type optical components used in the Figure descriptions are merely exemplary and the ordinary artisan will readily recognize the use of ST-type components in the illustration is in no way intended to limit the scope of the present invention. Notice that by comparing BOPA 460 illustrated in FIG. 4A with ST connector 412 illustrated in FIG. 4B, it can be seen that ST body 414 is present in both components. With respect to ST connector 412, ST body 414 secures ferrule 416 and fiber 418 in a predetermined position. By contrast, ST body 414 performs the function of an optical adapter body for securing protective sleeve 462, mini-borescope insertion tube 404, light rod 464 and optical rod 466 in a predetermined position with respect to BOPA 460. For purposes of inspecting coupling surfaces of optical fibers in an adapter portion of an optical port, body 414 may be fabricated as a substantial replica of that used on ST

adapter **412**. Recall that ST-type connectors are merely exemplary and that the present invention envisions the use of any type of component. One of ordinary skill in the art will recognize that body **414** may be modified for specialized applications in use with BOPA **460** or for accepting protective sleeve **462** with a larger, or even smaller, diameter than that of ferrule **416**. Furthermore, it may be useful to omit the locking mechanisms from body **414**, such as engagement channel **416**, when in use with BOPA **460** thus allowing the operator to readily change the field of view during inspection by reciprocating BOPA **460** forward and back from coupling surface **419**. In that case, the operator merely pulls BOPA **460** away from the optical port to increase the field of view and expand the target area. Removal of the engagement locks allows the operator to complete this motion in a smooth, consistent manner because the engagement locks cannot then interfere with the movement of BOPA **460**. In still another modification in accordance with another exemplary embodiment, body **414** is fabricated with slightly looser external dimensional tolerances for use with BOPA **460**. In so doing, an operator may obtain an even more complete view of an even wider target area simply by maneuvering BOPA **460** from side to side. While loosening the external dimensional tolerances might provide some benefit for inspecting an optical port containing a single optical fiber, expanding the target viewing area is even more helpful when inspecting optical ports containing multiple coupling surfaces from multiple optical fibers. In some cases, an optical port may contain coupling surfaces which lay outside the effective field of view for the mini-borescope. Merely pulling BOPA **460** away from the optical port may not increase the field of view enough to visualize outlying coupling surfaces while maintaining proper focal distance. In those cases, the looser external tolerances on body **414** allow the operator to sweep the optical axis laterally (peripherally) and thereby increase the effect field of view for inspecting an increased target area without increasing the focal distance.

Returning to the comparison Figures of **FIGs. 4A** and **4B**, notice that the diameter d_{ba} of borescope adapter **460** is less than or equal to that of the diameter d_f of the ferrule for a corresponding connector type, in this case, the ST-type connector. Recall that the coupling surface of an optical fiber is often recessed within the ferrule tube and disposed within an adapter portion of an optical port (observe ferrule tube **206** depicted in **FIG. 2**). It is unlikely that detailed images may be obtained with lens **467** and light shaft end **475** positioned external to the ferrule tube. Better images of the coupling surface are possible when lens **467** and light shaft end **475** are positioned internally within the ferrule tube itself. By assuring that the diameter d_{ba} of borescope adapter **460** is less than or equal to the diameter d_f of the ferrule, clearance is guaranteed for protective sleeve **462** to be inserted into the ferrule tube.

Finally, it should be understood that lens **467** and light shaft end **475** is protected from accidental damage during optical port inspections. To this end, notice also that borescope adapter **460** is configured such that the distance between the furthest extent of lens **467** and the forward-most shoulder of body **414**, d_{ib} , is less than the corresponding distance, d_{fb} , for SC connector **412** (*i.e.*, between coupling surface **419** and the forward-most shoulder of body **414**). Lens **476** is set back closer to body **414** in order to protect the lens from being accidentally scratched or damaged during insertion into an adapter. It should be further understood that the position of lens **476** with respect to body **414** is also a function of the optical focal distance of the particular type mini-borescope optics. Thus, lens **476** may be positioned even further from that of the respective end of ferrule **416** than that represented in the Figures in order to preserve the proper focal distance for the particular model of mini-borescope.

Turning now to **FIG. 5**, a cross-sectional view depicting a typical optical port inspection is illustrated with respect to an SC-type environment in accordance with an exemplary embodiment of the present invention. Here, a typical optical port (such as a bulkhead port) is represented comprising SC-type adapter **502** shown mated with SC-type

connector **512**. SC-type connector **512** is similar to that described above with respect to **FIGs. 1 and 2** comprising fiber **518** circumferentially enclosed by ferrule **516** and both being secured in ST-type body **514**. Inspecting an optical port that is configured as shown in **FIG. 5** involves an operator opening shutter **508** to expose the interior of SC adapter **520** along with coupling surface **519**. Next, the operator inserts mini-borescope insertion tube **506** into ferrule tube **506** by engaging body **514** of mini-borescope adapter **560** as depicted. Notice that optical lens **576** is positioned adjacent to, but in not contact with, coupling surface **519** of fiber **518** within ferrule tube **506**, thus maintaining the proper focal distance. The cavity formed in ferrule tube **506** between optical lens **576** and coupling surface **519** also allows light emitted from light shaft end **575** to eliminate coupling surface **519**.

It should also be understood that, although mini-borescope adapter **560** is depicted fully engaged within ST adapter **502**, a minimal gap exists between the exterior of body **514** and the interior of adapter body **504**. This gap allows space for manipulating mini-borescope adapter **560**, thus allowing the operator to redirect the viewing axis onto different portions of ferrule **516**. While this feature is somewhat useful for single fiber connections and applications, the ability to redirect the viewing axis onto multiple fibers is more helpful for inspecting multiple coupling surfaces on connectors which have manifolds for simultaneously securing multiple optical fibers.

The accumulation of dirt, dust and other debris (along with streaks from alcohol, acetone, oil stains and residual films) on the coupling portion of a fiber reduces the effectiveness of the fiber optic system and increases errors in data transmission. Recently, in an effort to diminish the occurrence of this problem, optical component manufacturers have utilized shutters to protect the coupling surface of an optical fiber. While shutters on connectors and adapters have been known in the industry, typically shutters have been designed as a manually operated feature wherein an operator manually open the shutter in order to insert a connector, as described above with respect to **FIGs.**

1, 2 and 5. Additionally, shutters have normally been incorporated only on an adapter body and not on optical connectors. Coupling surfaces located on connector ends were protected by using replaceable caps which were removed prior to engaging the connector into an adapter and subsequently replaced after the connector was disconnected. The prior art system of external shutters and replaceable connector caps was manually extensive, requiring operators to perform extra procedures to lessen the occurrence of contamination. Operators often shortcutting the system resulting in unwanted contamination on coupling surfaces.

Component manufacturers came to realize that in order to make their products more reliable, a mechanism had to be provided wherein the coupling end of a fiber was always protected whether or not the fiber was in use. Moreover, the mechanism had to be automatically actuated, thereby relieving operators from performing extra manual steps necessary to protect the coupling surfaces. An example of such a connector and adapter pair is that of the *LX.5* component system (a trademark of and available from ADC Telecommunications, Inc., P. O. Box 1101, Minneapolis, MN 55404-1101).

FIGs. 6A through 6E are cross-sectional diagrams depicting the stages of insertion of an *LX.5* connector into an *LX.5* adapter in accordance with the prior art. As discussed above with respect to other prior art connector and adapter systems, **FIGs. 6A through 6E** will be described only with the detail necessary for practicing the present invention. Other features and advantages of the connector/adapter system may be present in addition to those described below. The specific connector and adapter types being illustrated in **FIG. 6** are that of *LX.5*-type connector/adapter components (*i.e.*, *LX.5* connector **612** and SC adapter **602**), used herein as a means for describing the applicability of the present invention to optical components with automatically-actuating shutter systems, in contrast to manually-actuated shutter systems described above. An artisan having ordinary skill in the art will readily recognize that the use of an *LX.5*-type component is merely exemplary and that any type of connector component which

incorporates automatically-actuating shutter systems might be substituted for the SC-type components without departing from the original scope and intent of the present invention.

Optical connector/adaptor system **600** consists of *LX.5* adapter **602** and *LX.5* connector **612**. With respect to *LX.5* connector **612**, *LX.5* connector **612** comprises external shutter **620** which is rigidly connected to shutter cam **622** which is pivotally mounted on *LX.5* connector **612**. As will be described in more detail below, shutter cam **622** cooperates with corresponding cam pin **609** on *LX.5* adapter **602** for automatically actuating external shutter **620** open and closed simultaneously with engagement and disengagement of connector **612** to adapter **602**. External shutter **620** remains in the normally closed position thereby protecting coupling surface **619** when connector **612** is not in use, when engaged with *LX.5* adapter **602**; however, external *LX.5* connector shutter **620** pivots into the open position. *LX.5* connector **612** utilizes internal adapter shutter cam **624** for opening internal shutters **608** disposed within *LX.5* adapter **602**. Opening and closing the shutters on *LX.5* component system **600** will be discussed below with respect to **FIGs. 6A** through **6E**. In addition to the above-described components, *LX.5* connector **612** comprises ferrule **616** for containing fiber **618**, which is terminated in coupling surface **619** for transmitting and receiving optical signals for another optical component. Connected to body **614** is depressible latch **626** which, during engagement with *LX.5* adapter **602**, is depressed enough to provide clearance to engage body **604** and to cooperate with combination latch cam and catch **607** on body **604** for securing *LX.5* connector **612** to body **614** of *LX.5* adapter **602**.

With respect to adapter **602**, adapter **602** is shown mounted on bulkhead **620** as might be present on any one of a number of devices having an optical port (*e.g.*, optical amplifier, optical switch, optical cross connector, etc.). Adapter **602** comprises ferrule tube **606** that is secured within body **604**. Ferrule tube **606** is of sufficient diameter to receive ferrule **616** of *LX.5* connector **612** and is protected at either end by a pair of internal shutters **608**. Internal shutters **608** are held in a normally closed position via

torsion springs on the respective shutters except when accommodating ferrule **616**. In the closed position, internal shutters **608** protect coupling surface **619** of fiber **618** from airborne contaminate that might otherwise occlude the optical transmission. Also contained within body **604** is a combination latch cam and catch **607** that cooperates with depressible latch **626** and a pair of shutter cam pins **609** that engage and cooperate with shutter cam **622** disposed on *LX.5* connector **612** for actuating connector shutter **620** during insertion of *LX.5* connector **612**.

The operation of the shutter system of the *LX.5* adapter system will now be described with respect to **FIGs. 6A** through **6E**. Notice that as depicted in **FIG. 6A** connector **612** is aligned and partially enters the internal cavity of *LX.5* adapter **602**. Turning now to **FIG. 6B**, the exterior face of exterior connector shutter **620** is in contact with the exterior wall of interior adapter shutter **608** which is shown partially open. With respect to **FIG. 6C**, *LX.5* connector **612** continues to be inserted within *LX.5* adapter **602** wherein internal adapter shutter **608** is forced further open to accommodate the vertical extent of external connector shutter **620**. Notice also at this point in the mating that internal shutter cam **624** makes initial contact with internal shutter **608**. Turning now to **FIG. 6D**, *LX.5* connector **612** travels further within body **604** of *LX.5* adapter **602** at which point internal shutter cam **624** fully engages internal shutter **608** and forces the shutter to open to its fullest open extent. Notice also that external connector shutter **620** is now partially opened. External shutter **620** rotates to the open position in response to cam pin **609** engaging a U-shaped cavity disposed within external connector shutter cam **622**. As *LX.5* connector **612** is thrust further within body **604** of *LX.5* adapter **604**, connector shutter cam **622** rotates in response to relative movement cam pin **609** with respect to the position of *LX.5* connector **612**. Connector shutter **620** continues to open as cam pin **609** traverses the lateral extent of connector shutter cam **622**. In its final position shown in **FIG. 6E**, cam pin **609** has completely traversed the extent of external connector shutter cam **622** causing external connector shutter **620** to rotate in its full open

position. There, ferrule **616** and fiber **618** have been fully accepted within ferrule tube **606** causing coupling surface **619** to reach its deepest depth within ferrule tube **606**. Latch **626** is received by cam and latch **607**, thereby securing *LX.5* connector **612** to *LX.5* adapter **602**. It should be understood that the aforementioned connectors may be
5 exemplary. Other connectors with the internal and external shutters, whether manually or automatically operated, will have features and attributes unique to those connector and adapter systems.

Turning now to **FIGs. 7A** and **7B**, a cross-sectional diagram of an mini-borescope-to-optical port adapter in accordance with an exemplary embodiment of the
10 present invention, is depicted adjacent to a cross-sectional diagram of a typical *LX.5* connector as was described above. **FIGs. 7A** and **7B** are substantially similar to **FIGs. 4A** and **5B** in many respects and that the primary distinctions between the respective Figures in the manner in which the automatically-actuated shutter system functions shown in **FIGs. 7A** and **7B**. With respect to **FIG. 7A**, *LX.5* BOPA **760** is shown fastened
15 to mini-borescope insertion tube **704** as described above with respect to **FIGs. 3, 4A** and **4B**. Here, *LX.5* BOPA **760** is connected to mini-borescope insertion tube **704** using locking means **768** in an identical manner as employed for any other optical adapter such as that described above with respect to SC adapter **460** on **FIG. 4A**. BOPA **760** comprises body **714** which may be permanently or temporarily affixed to protective
20 sleeve **762**. If permanently mounted on protective sleeve **762**, then protective sleeve **762** is unlocked and replaced from mini-borescope insertion tube **704** for each different type of optical port to be inspected. If, on the other hand, body **714** is temporarily affixed to protective sleeve **762**, then the mini-borescope can be reconfigured for different optical component types by merely interchanging body **714** with another component type body.

25 Optical adapter body **714** of BOPA **760** shown in **FIG. 7A** is substantially similar to that shown in **FIG. 7B** of body **714** of *LX.5* connector **712**. Functionally, each of body **714** comprises external connector shutter **720** and cooperating external connector shutter

cam **722** for protecting either lens **767** on optical rod **768** for BOPA **760** or coupling surface **719** of fiber **718** for *LX.5* connector **712**. Also depicted in the respective Figures is internal adapter shutter cam **724** for opening an internal adapter shutter and depressible latch **726** for securing BOPA **760** to an adapter. It should be understood that, in accordance with one embodiment of the present invention locking mechanisms, such as depressible latch **726**, may be omitted from BOPA **760** in order to allow the operator to readily change the field of view during inspection by reciprocating BOPA **760** forward and back from coupling surface **719**. Removal of depressible latch **726** allows the operator to complete this motion in a smooth, consistent manner because the lock does not retard the movement.

BOPA **760** differs from *LX.5* connector **712** in that rather than body **714** securing ferrule **716** and optical fiber **718** in a predetermined position, body **714** secures protective sleeve **764** which surrounds mini-borescope insertion tube **704**, light rod **764** and optical rod **766**. Again, protective sleeve **764** is disposed around mini-borescope insertion tube **704** to provide the necessary rigidity for engaging BOPA **760** in optical ports. Optical rod **766** is necessary for transmitting images of a target received from lens **767** to imaging electronics and ultimately the display screen, while light rod **764** is a light medium for transmitting light from a light source to light rod end **765** for illuminating the target.

With respect to still another modification in accordance with another exemplary embodiment, body **714** may be fabricated with slightly looser external dimensional tolerances for use with BOPA **760** which allows the operator more freedom to manipulate BOPA **760** from side to side, thus able to acquire images from a larger target area. Loosening the external dimensional tolerances is even more helpful in situations involving inspection of optical ports containing multiple coupling surfaces from multiple optical fibers.

Returning to the comparison Figures of **FIGs. 7A** and **7B**, notice that the diameter d_{ba} of borescope adapter **760** is less than or equal to that of the diameter d_f of ferrule **716** for a corresponding connector type (the *LX.5* component type is shown). By assuring that the diameter d_{ba} of protective sleeve **762** on mini-borescope adapter **760** is less than or
5 equal to that of the diameter d_f of ferrule **716**, clearance is guaranteed for protective sleeve **762** to be inserted into the ferrule tube.

Mini-borescope adapter **760** should be configured such that the likelihood of damage to lens **767** and light shaft end **775** is lessened during inspections. To this end, notice also that borescope adapter **460** is configured such that the distance between the
10 furthest extent of lens **467** and the forward-most shoulder of body **414**, d_{lb} , is less than the corresponding distance, d_{fb} , for *LX.5* connector **712** (*i.e.*, between coupling surface **719** and the forward-most shoulder of body **714**). Lens **776** is set back closer to body **714** in order to protect the lens from being accidentally scratched or damaged during insertion into an adapter. It should be further understood that the position of lens **776** with respect
15 to body **714** is also a function of the optical focal distance of the particular type mini-borescope optics. Thus, lens **776** may be positioned even further from that of the respective end of ferrule **716** than that represented in the illustrations in order to preserve the proper focal distance for the particular model of mini-borescope while borescope adapter **760** is fully engaged within the optical port being inspected.

20 In accordance with an exemplary embodiment of the present invention, when BOPA **760** is attached to mini-borescope insertion tube **704**, an optical port can be easily engaged and a coupling surface enclosed with no more difficulty than engaging an optical connector to an optical port (BOPA **760** and the optical port should, of course, be compatible component types).

25 **FIGs. 8A** through **8E** are cross-sectional diagrams depicting an *LX.5*-type mini-borescope-to-optical port adapter engaging an *LX.5*-type adapter for inspecting a coupling surface of the optical fiber in accordance with an exemplary embodiment of the

present invention. **FIGs. 8A through 8E** correspond to **FIGs. 6A through 6E** in that each corresponding Figure shows a key insertion stage between a connector (or optical adapter) and an adapter of an optical port. Therefore, because the key insertion stages of the mating process have been discussed in great detail above, the discussion of **FIGs. 8A through 8E** will focus primarily on differences between engaging a connector and engaging a borescope-to-optical port adapter into an adapter on an optical port.

With respect to the present diagrams, *LX.5* connector **812** is fully engaged in *LX.5* adapter **802** and coupling surface **819** of fiber **818** is in position for inspection in ferrule tube **806**. **FIGs. 8A through 8E** show insertion positions of BOPA **860** with respect to *LX.5* adapter **802**. With respect to **FIGs. 8A - 8D**, an operator inserts BOPA **860** into adapter **802** while external connector shutter **820** on BOPA **860** remains closed, thereby protecting lens **867** of optical rod **866** until body **814** is fully engaged within body **804**. At that point, as depicted in **FIG. 8B**, the exterior face of exterior connector shutter **820** is in contact with the exterior wall of interior adapter shutter **808** causing it to partially open. With respect to **FIG. 8C**, BOPA **860** continues to engage *LX.5* adapter **802** and internal adapter shutter **808** is forced open to accommodate the vertical extent of external connector shutter **820**. Simultaneously, internal shutter cam **824** contacts internal shutter **808** causing it to open to its fullest extent. As BOPA **860** (**FIG. 8D**) continues into body **804** of *LX.5* adapter **802**, internal shutter cam **824** fully engages internal shutter **808** and opens it to its fullest extent. At this point, external connector shutter **820** is not completely opened until cam pin **809** engages a U-shaped cavity on connector shutter cam **822** and traverses it.

With respect to **FIG. 8E**, notice that cam pin **809** has completely traversed the extent of external connector shutter cam **822**, thereby completely opening the shutter **820**. In the depicted position, BOPA **860** has not completely engaged *LX.5* adapter and protective sleeve **862** has been only partially accepted within ferrule tube **806**. At this point the operator may be within the focal distance of the particular model of mini-

borescope and able to view couple surface **819** or ferrule tube **806** for occlusions or scratches. However, the operator might instead continue inserting BOPA **860** into *LX.5* adapter **802** for a closer view of the target surface. That notice that here the forward movement of depressible latch **826** will be impeded by combination latch cam and catch **807** on body **804**. Therefore, in accordance with one exemplary embodiment of the present invention, depressible latch **826** is omitted from optical adapter **870** in order to allow the operator to readily change the field of view during inspection by reciprocating BOPA **860** forward and back from coupling surface **819**.

The present invention alleviates the problems associated with troubleshooting opticals port for optical contamination. The present apparatus and process provides accurate diagnostic results thereby avoiding unnecessary board replacement by immediately identifying optical surface defects. As illustrated in the prior method of cleaning, measure power, "cleaning" is abbreviated using the present invention because occlusions and scratches that result in power loss are positively identified, and the outcome of subsequent cleaning attempts are likewise quantifiable. Additionally, the chance of retina damage due to accidental contact with power laser sources is greatly reduced because the target surface is not directly visualized, instead an image of the target surface is displayed. Finally, although the present invention has been described with respect to an optical transmission system, the present invention is equally suitable for inspecting other types of ports and connectors, such as electrical.

The corresponding structures, materials, acts, and equivalents of all means or step plus function elements in the claims below are intended to include any structure, material, or act for performing the function in combination with other claimed elements as specifically claimed. The description of the present invention has been presented for purposes of illustration and description, but is not intended to be exhaustive or limited to the invention in the form disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art. The embodiment was chosen and described in order

to best explain the principles of the invention and the practical application, and to enable others of ordinary skill in the art to understand the invention for various embodiments with various modifications as are suited to the particular use contemplated.

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